Beam collimation in the beam transfer line from 8 GeV linac to the Main Injector

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$P \cdot c = 8.88889\, GeV$,
$dP/P = 1.125 \cdot 10^{-3}$,
95% normalized emittance $\varepsilon = 6\ \pi\ mm \cdot mrad$.

phase advance per cell (ψ)	dispersion (η)	$dX = \eta \cdot dP/P$	β_x	$3\sigma_x$	beam line length
degree	m	mm	m	mm	m
Two-wave dispersion beam line					
45	8.88	10.0	69.0	8.1	585.75
60	8.85	10.0	76.9	8.5	560.88
90	8.80	9.9	110.2	10.2	528.76

Table 1: Beam line consists of two waves of dispersion (720^o). Off-momentum collimator jaws (stripping foils) are located at $3\sigma_x$ from both sides of the beam. Displacement of off-momentum particles dX should be bigger than $3\sigma_x$ of the beam. Displacement dX is approximately the same for all cases, but $3\sigma_x$ is sufficiently less for 45^o and 60^o lattices compared to 90^o lattice. This is an advantage for off-momentum collimation.

phase advance per cell (ψ)	dispersion (η)	$dX = \eta \cdot dP/P$	β_x	$3\sigma_x$	beam line length
degree	m	mm	m	mm	m
One-wave dispersion beam line					
60	19.8	22.3	115.3	10.4	420.66

Table 2: Beam line consists of one wave of dispersion (360^o). Off-momentum collimator jaws (stripping foils) are located at $3\sigma_x$ from both sides of the beam. Displacement of off-momentum particles dX should be bigger than $6\sigma_x$ of the beam.

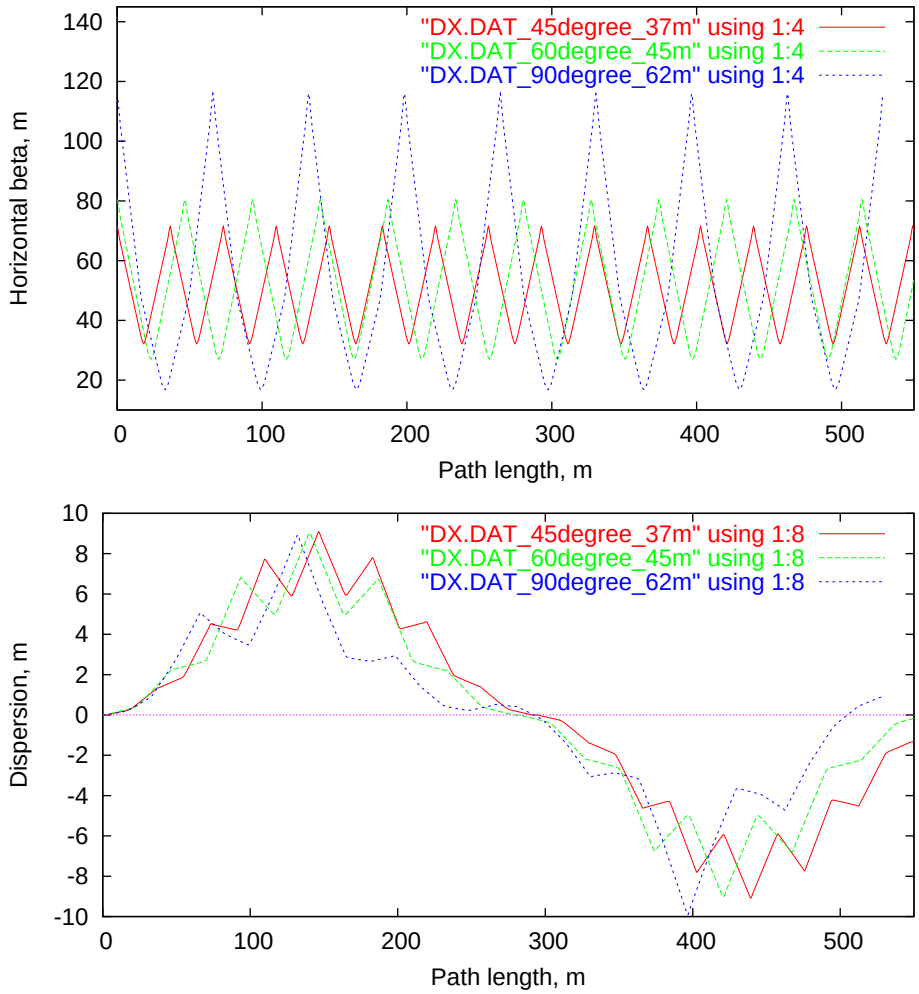

Figure 1: Beta function (top) and dispersion (bottom) in the 45^o, 60^o and 90^o phase advance per cell achromatic lattices. 16 cells of 45^o, 12 cells of 60^o and 8 cells of 90^o are shown. This lattice is used for off-momentum collimation by two stripping foils located at $3\sigma_x$ from both sides of the beam in two places located at 360^o between them, with positive and negative dispersion. Displacement of off-momentum particles dX should be bigger than $3\sigma_x$ of the beam. 45^o and 60^o lattices have smaller beta compared to the 90^o lattice for the same amount of dispersion and total length. This is advantage for off-momentum collimation (see Table 1).

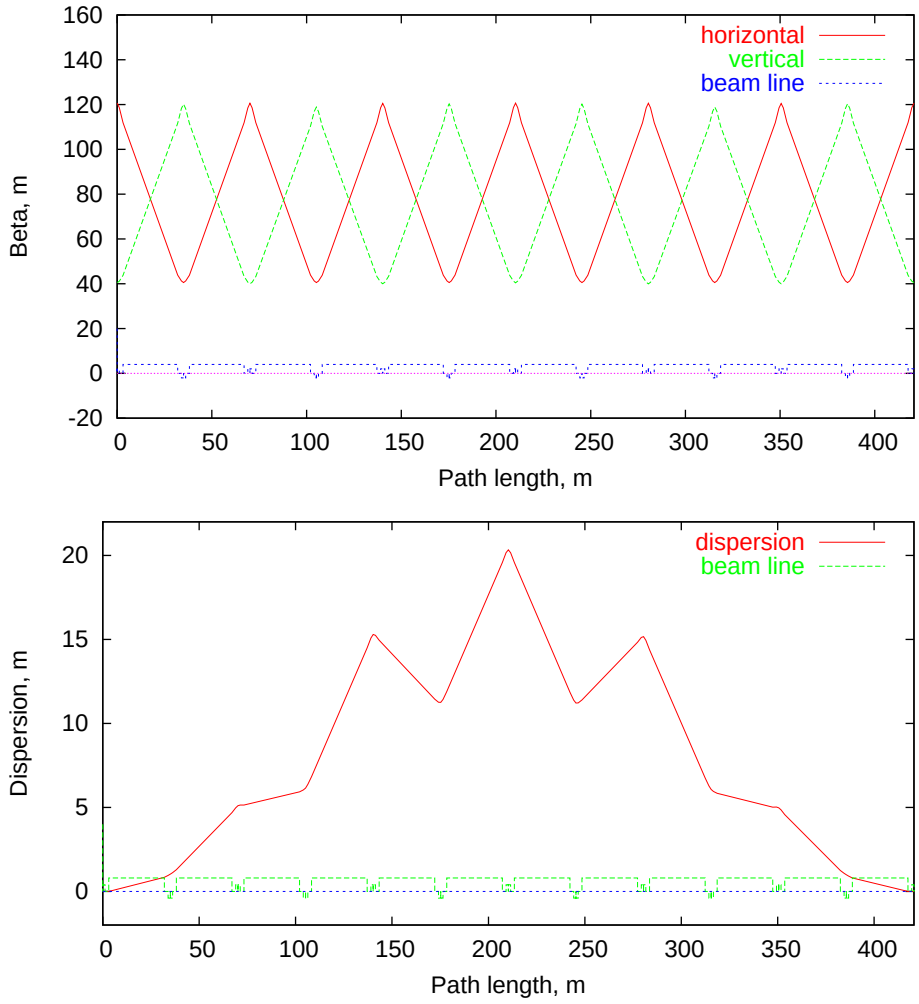

Figure 2: Beta function (top) and dispersion (bottom) in the 60^o phase advance per cell achromatic lattices. 6 cells are shown. This lattice is used for off-momentum collimation by two stripping foils located at $3\sigma_x$ from both sides of the beam in a place with maximum dispersion. Displacement of off-momentum particles dX should be bigger than $6\sigma_x$ of the beam.

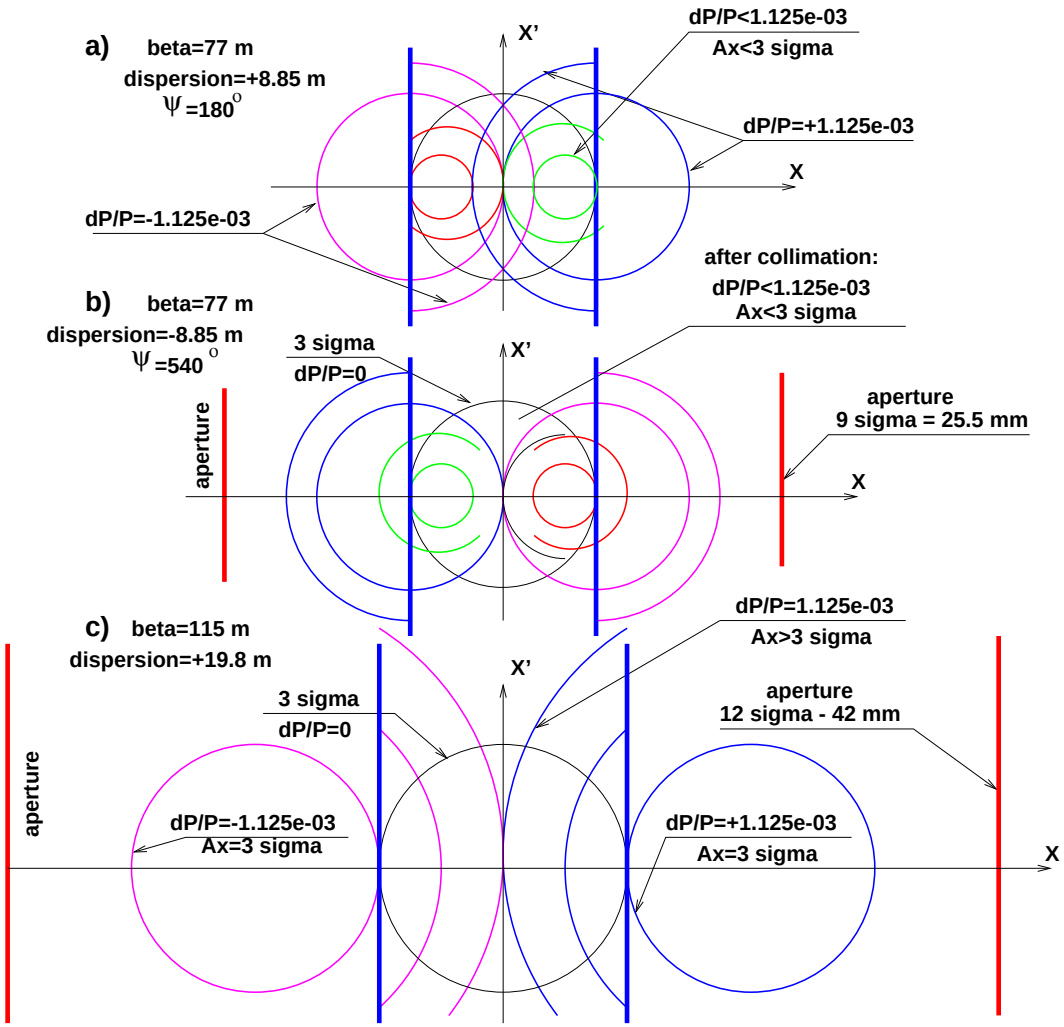

Figure 3: Off-momentum collimation in the line with two waves of dispersion: top - in the location with positive dispersion, and middle - in the location with negative dispersion. Bottom - collimation in the line with one wave of dispersion. As amplitude collimators are located at 3σ, the system performs collimation of particles with $A > 3\sigma$ and $dP/P > 1.125 \times 10^{-3}$ in both cases. Minimal horizontal aperture of the elements is equal to $6\sigma_x$ in the first case, and $9\sigma_x$ in the second one. If one assumes a distance between the beam pipe and the edge of the beam ($3\sigma_x$) equal to $3\sigma_x$, the required radius of aperture is equal to $9\sigma_x$ in the first case, and $12\sigma_x$ in the second one. This gives the beam pipe diameter of 51 mm for the first case, and 84 mm for the second one. There are two possible solutions for collimation of the beam before injection to the Main Injector: first - to use two-wave dispersion lattice 560 m long with aperture of D51 mm, second - to use one-wave dispersion lattice 420 m long with aperture of D84 mm

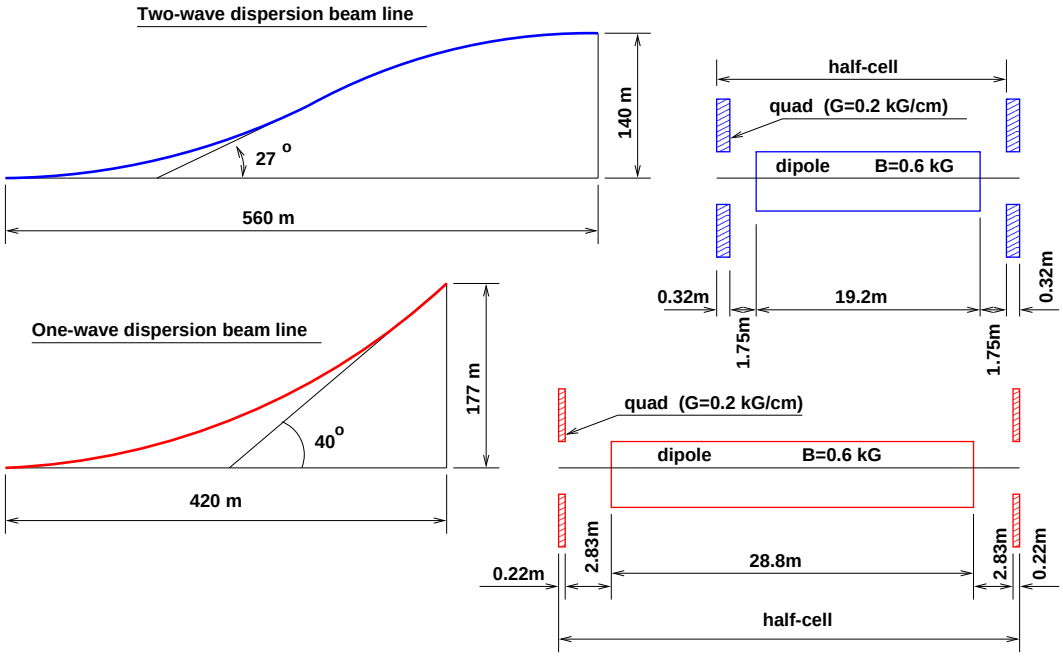

Figure 4: Two-wave dispersion (top) and one-wave dispersion (bottom) beam lines top view.